Neurocognitive Responses to a Single Session of Static Squats With Whole Body Vibration

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Abstract

Amonette, WE, Boyle, M, Psarakis, MB, Barker, J, Dupler, TL, and Ott, SD. Neurocognitive responses to a single session of static squats with whole body vibration. *J Strength Cond Res* 29(1): 96–100, 2015—The purpose of this study was to determine if the head accelerations using a common whole body vibration (WBV) exercise protocol acutely reduced neurocognition in healthy subjects. Second, we investigated differential responses to WBV plates with 2 different delivery mechanisms: vertical and rotational vibrations. Twelve healthy subjects ($N = 12$) volunteered and completed a baseline (BASE) neurocognitive assessment: the Immediate Postconcussion Assessment and Cognitive Test (ImPACT). Subjects then participated in 3 randomized exercise sessions separated by no more than 2 weeks. The exercise sessions consisted of five 2-minute sets of static hip-width stance squats, with the knees positioned at a 45° angle of flexion. The squats were performed with no vibration (control [CON]), with a vertically vibrating plate (vertical vibration [VV]), and with a rotational vibrating plate (rotational vibration [RV]) set to 30 Hz with 4 mm of peak-to-peak displacement. The ImPACT assessments were completed immediately after each exercise session and the composite score for 5 cognitive domains was analyzed: verbal memory, visual memory, visual motor speed, reaction time, and impulse control. Verbal memory scores were unaffected by exercise with or without vibration ($p = 0.40$). Likewise, visual memory was not different ($p = 0.14$) after CON, VV, or RV. Significant differences were detected for visual motor speed ($p = 0.006$); VV was elevated compared with BASE ($p = 0.01$). There were no significant differences ($p = 0.26$) in reaction time or impulse control ($p = 0.16$) after exercise with or without vibration. In healthy individuals, 10 minutes of 30 Hz, 4-mm peak-to-peak displacement vibration exposure with a 45° angle of knee flexion did not negatively affect neurocognition.

Key Words vibration exercise, safety, head acceleration, rehabilitation exercise

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Introduction

Whole body vibration (WBV) is an innovative neuromuscular exercise tool. When undergoing vibration training, a person stands on a metal plate that oscillates at frequencies varying from 10 to 90 Hz with peak-to-peak amplitudes of 0.08–4.00 mm (13). These vibration parameters may result in whole body accelerations up to or exceeding 4 times the bodyweight and are thought to induce a stretch reflex response, resulting in stimulation of 1a afferent neurons (1). Similar to resistance exercise, vibrations may also result in motor neuron activation as a result of the force imparted to the skeleton by the accelerating platform (4).

Although studies supporting the potential use of vibration for health benefits date back to 1936, the popularity and widespread use have increased significantly in recent years, expanding into the fitness, rehabilitation, and professional sport industries (16). There is evidence supporting the use of WBV training as a mechanism to excite skeletal muscle (1,4) and potentiate an acute increase in power (3). Compared with sedentary control conditions, WBV exercise has been shown to elicit beneficial training responses, including improvements in muscle strength (9), muscle power (10), increased bone mineral density (19), and reduction in back pain (15). Evidence also supports WBV as a tool to minimize bone loss during bed rest compared with control (14). The recent research evidence and increased market availability of vibration platforms have expanded WBV exercise usage in strength, conditioning, fitness, and rehabilitation settings.

In contrast to the potential positive effects, long-term exposure to vibration can be detrimental to the human skeleton and is a known occupational hazard. Vibration exposure is closely monitored in certain occupations because it has been demonstrated that chronic vibration may result in a variety of musculoskeletal injuries (11,12,20,21,23).

Abercromby et al. (2) recently demonstrated that exposure to a typical vibration exercise regimen exceeded the recommended daily occupational exposure as defined by ISO 2631-1. Moreover, their data suggest that when exercising on a WBV platform, a significant amount of vibration is transmitted through the skeleton to the head.

Because of the previously reported head accelerations from WBV exercise, it may be particularly important to investigate the safety (2). Vibration exercise is now common in many athletic facilities, rehabilitation clinics, and corporate gyms. It is used routinely by some practitioners as a neuromuscular training tool, but there is minimal research to support the safety of vibration exercise. Therefore, the purpose of this study was to determine if the head accelerations resulting from an acute bout of exercise using a standard WBV exercise protocol–decreased neurocognition in healthy adults. Second, we investigated differential responses to WBV plates with 2 delivery mechanisms: vertical (vertical vibration [VV]) and rotational (rotational vibration [RV]). It was hypothesized that exposure to a single bout of WBV exercise would result in a measurable reduction in cognition.

Methods

Experimental Approach to the Problem

A randomized crossover study design was used to assess the hypothesis. Subjects were tested on 4 different days, with 3–14 days between test sessions. In the initial testing session, subjects completed the informed consent form and anthropometric data were collected. Then, they underwent a baseline (BASE) testing session using the Immediate Postconcussion Assessment and Cognitive Test (ImPACT; ImPACT Applications, Inc., Pittsburgh, PA, USA) (7). Each subject returned to the laboratory 3 additional times, at a similar time of day (±1 hour), to perform 1 of 3 conditions: (a) static exercise without vibration (control [CON]), (b) static exercise with a synchronously or vertically vibrating plate (VV), and (c) static exercise with an asynchronously or rotational vibrating plate (RV). The 3 exercise conditions were completed by all subjects in random order on different days. Exercise sessions were followed immediately by ImPACT assessment.

Subjects were not permitted to consume food 2 hours before testing, ingest caffeine 4 hours before testing, or ingest alcohol or nicotine 8 hours before testing. It was also recommended that subjects obtain similar sleeping patterns before each day of testing. This was confirmed through a pretest screening form completed before each session. The participants wore the same athletic shoes during each test to ensure similar dampening of vibration across sessions.

Subjects

Eight men and 4 women ($N = 12$; age: 28.2 ± 6.4 years; height: 174.3 ± 2.3 cm; weight: 82.7 ± 4.6 kg) volunteered to participate. The subjects were recreationally active but did not routinely use WBV for exercise. The 12 subjects were recruited from the sponsoring university and the surrounding community. They were apparently healthy at the time of testing. Subjects were excluded from the study if they had a history of back pain, acute inflammation of the pelvis or lower extremity, acute thrombosis, bone tumors, recent fracture, recent implants, gallstones, kidney or bladder stones, any disease of the spine, peripheral vascular disease, or brain injury or were pregnant. The study procedures were evaluated and approved by the committee for the protection of human subjects (CPHS) at the sponsoring university. Each participant read and signed an informed consent approved by the CPHS, was given a verbal explanation of the procedures, and was encouraged to ask questions throughout the study.

Procedures

Whole Body Vibration Exercise. During each exercise session, subjects completed 5 sets of 2-minute repetitions of static squats. The subjects were positioned on the vibration plate with their feet 20.6 cm apart, with 45° of knee flexion. One minute of recovery was provided between sets. During the CON session, subjects completed all exercise sets standing on the vibration platform with the machine powered off. The VV session was completed using a Power Plate vibration platform (Power Plate North America, LLC, Culver City, CA, USA) set to 30 Hz and 4 mm of peak-to-peak vertical displacement. The RV sessions were performed with an identical frequency (30 Hz) and amplitude (4 mm) on a Galileo 2000 vibration platform (Orthometrix, Inc., White Plains, NY, USA). The amplitude using the RV plate was manipulated by standardizing the subject stance width at 20.6 cm; an identical stance width was used for CON, VV, and RV conditions (1,2). The vibration frequency and intensity were selected because they are commonly used parameters that are associated with positive increases in strength and power (3). Additionally, no side effects other than itching of feet have been reported with this protocol.

Neurocognitive Assessment. Neurocognitive assessments were completed immediately after each exercise session using a 25-minute computerized test battery (ImPACT). The ImPACT is a Web-based assessment, traditionally used to establish preinjury and postconcussion performance in children, adolescents, and young adults who participate in sports. It provides useful information for clinicians determining when it is safe for concussed patients to return to work, school, or sport competition. It has alternative forms for test-retest situations and yields individual scores measuring attention, visual and verbal memory, visual motor speed, reaction time, and numerical sequencing ability. The results from these tasks collapse to provide 4 composite scores: verbal memory, visual memory, motor processing speed, and reaction time. A distractor task also yields a score indicating the number incorrect throughout the impulse control testing sequence.

Table 1. Composite summary scores for the 5 cognitive domains tested.*

Cognitive domain	BASE	CON	VV	RV
Verbal memory (% correct)	90.5 ± 7.4	90.8 ± 6.7	92.3 ± 6.1	93.0 ± 5.1
Visual memory (% correct)	78.8 ± 16.0	75.3 ± 14.8	77.1 ± 15.7	76.4 ± 13.7
Motor processing speed (% correct)	40.3 ± 5.3	42.5 ± 4.5	43.2 ± 6.1†	41.6 ± 5.1
Reaction time (s^{-1})	0.60 ± 0.06	0.58 ± 0.05	0.57 ± 0.06	0.59 ± 0.07
Impulse control (# incorrect)	4.6 ± 2.6	6.0 ± 3.3	6.3 ± 3.3	4.7 ± 2.7

*BASE = Baseline; CON = Control; VV = vertical vibration; RV = rotational vibration.
†Indicates significance at the $p \leq 0.05$ level compared with BASE.

The ImPACT has been shown to be a reliable and valid tool for neurocognitive assessment after head acceleration injuries (6,8,17,18,22). Reliable change estimates based on 80% confidence intervals for each tested domain have been published previously (7). Although ImPACT is routinely used to assess cognitive functioning in concussed athletes, it is a versatile tool used to measure behavioral correlates of brain function in other syndromes. It has also been used previously to assess acute cognitive changes resulting from treadmill running to exhaustion (5). The ImPACT was completed on a laptop computer (Dell, Inc., Austin, TX, USA) using an external mouse with subjects seated in a quiet room. After subjects were familiarized with the ImPACT procedures and given opportunities to ask questions, the investigators left the testing room until the subject completed the test.

Statistical Analyses

Statistical analyses were completed using SigmaPlot 14.0 (Systat, Inc., San Jose, CA, USA). Because of the scoring system used by ImPACT for verbal memory (% correct), visual memory (% correct), and motor processing speed (% correct), significant differences from BASE for these cognitive domains were determined using repeated measures analysis of variance (ANOVA) on ranked data (nonparametric test). If the F-ratios were significant, follow-up Wilcoxin signed-rank tests were completed. Statistical hypotheses related to reaction time (per second) and impulse control (number incorrect) were assessed using separate 1-way ANOVAs (parametric test). If the F-ratios were significant, Holms-Sidak (ANOVA) post hoc test was used for pairwise comparison vs. the BASE condition. Alpha was set at $p \leq 0.05$. Effect size calculations (Cohen's d) were completed and reported on all tested conditions (CON, VV, and RV) compared with BASE.

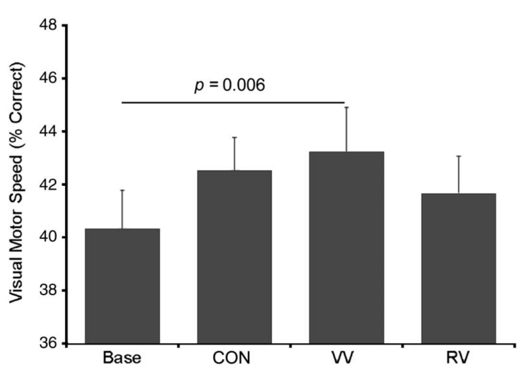

Figure 1. Differences in visual motor speed resulting from static squats with and without vibration.

Results

Table 1 provides the BASE and postexercise scores for verbal memory, visual memory, visual motor speed, reaction time, and impulse control. There were no significant changes in verbal memory scores ($p = 0.40$). BASE scores were similar to CON ($d = 0.04$), VV ($d = 0.26$), and RV ($d = 0.40$). Likewise, visual memory was similar to BASE ($p = 0.14$) and was not significantly different after any of the exercising conditions. CON ($d = 0.48$), VV ($d = 0.11$), and RV ($d = 0.16$) were similar to BASE. Significant differences were detected for motor processing speed ($p = 0.006$). VV ($d = 0.51$) was significantly elevated ($p < 0.006$) compared to BASE (Figure 1). However, CON ($d = 0.45$) and RV ($d = 0.25$) were similar to BASE. There were no significant differences ($p = 0.26$) in reaction time compared with BASE in CON ($d = 0.23$), VV ($d = 0.31$), and RV ($d = 0.16$). Finally, impulse control was unaffected ($p = 0.16$) by CON ($d = 0.47$), VV ($d = 0.57$), and RV ($d = 0.03$).

Discussion

Exercise in conjunction with WBV is a fitness and sports industry trend with some evidence to support its effectiveness. However, the literature investigating the potential safety risks of exercise with WBV is less robust. The data from this investigation suggest that an acute bout of static squats with 45° of knee flexion accompanied by WBV does not affect visual or verbal memory, reaction time, or impulse control measured using ImPACT, but motor processing speed may be increased after VV.

Although most recent research has focused on the positive benefits of vibration exercise, there is a substantial body of literature, primarily from occupational studies, suggesting that vibration may be detrimental to the human skeleton (11,12,20,21,23). Moreover, previous research indicates vibration exercise results in significant head accelerations (2). Based on these data, it was hypothesized that 10 minutes of vibration exposure would result in a measurable decrease in neurocognition. This hypothesis was rejected because there were no detectable negative changes after WBV.

There are several possible explanations for the rejection of our hypothesis. In contrast to occupational exposure, vibration parameters associated with exercise are strictly monitored and precisely prescribed. Therefore, the head accelerations resulting from WBV may not be of significant amplitude and frequency to cause an acute disruption in cognition. This is a positive finding that may support the safe acute use of vibration plates in exercise training. However, it should be noted that participants in this study were exposed to a single vibration session lasting 10 minutes. It is unknown if long-term repetitive use or acute bouts of greater duration result in detrimental effects.

It has been demonstrated previously that the magnitude of acceleration imparted to the head with WBV is dependent on knee angle (2). Specifically, research indicates that there is a minimal dampening of mechanical energy transfer through the skeleton with small knee flexion angles. Abercromby et al. (2) showed that peak head acceleration during WBV occurs with knee flexion of 10–15°. Conversely, when an individual flexes their knees, hips, and ankles in a squatting motion, mechanical energy transfer to the head is reduced, resulting in decreased head accelerations. Therefore, it could be that the knee angle used in this study (45°) minimized the head acceleration and thus resulted in no negative effects from vibration.

Strength and rehabilitation practitioners prescribe vibration exercise with dynamic squatting movements, isometric squats with smaller knee flexion angles than those tested in this study, and upper-body exercise with the hands or hips positioned on the plate. Moreover, exercises with external load are also prescribed in practice to potentially increase the neuromuscular response. Some populations using vibration platforms as an exercise or rehabilitation tool may not be able to safely flex their knees to 45° because of functional limitations, injury, or poor muscular strength and endurance. The results of this study are specific to isometric body weight squats with 45° of knee flexion and do not support the safety of other routinely prescribed postures and conditions. Therefore, future research is needed to test the safety of a variety of exercising postures, protocols, and loading conditions.

It may also be important to test the safety of other frequencies of vibration. The frequency selected in this study, 30 Hz, was the only common frequency between the 2 vibration plates. However, the RV plate allows the user to select from 1 to 30 Hz, and the VV allows for exercise at 30–60 Hz. It is possible that different frequencies may result in different head accelerations and thus dissimilar cognitive responses. Experiments testing other frequencies may be important to understand and minimize the potential negative effects of vibration.

It is possible that ImPACT may not be sensitive enough to detect cognitive changes resulting from vibrations. It was selected because it is a test commonly used to detect injuries resulting from head accelerations. The ImPACT is well validated, and it is one of the most common cognitive tests used in athletics, a population that widely uses WBV exercise. Additionally, ImPACT scores have been shown to be reduced with an acute bout of exhaustive treadmill exercise (5). For this reason, it was believed that if WBV negatively affected cognition, it would be detected by this test. Nevertheless, it may be beneficial to test these study parameters using other tools to corroborate these results.

Originally, it was hypothesized that vibration exposure would decrease cognition. However, we found that VV increased motor processing speed, which was an unexpected finding. Iverson et al. (7) studied the reliability of ImPACT testing in 56 nonconcussed and 41 concussed participants. They found that the reliable change estimate (80% confidence interval) for increases in motor processing speed was 7 points. Therefore, it is possible that our statistically significant finding might not be clinically meaningful.

Although the findings of this study are positive, it should be noted that the sample size was relatively small and homogeneous (i.e., young active adults). It is unlikely that a different population would produce contradictory results, but future replication of these data is important for establishing the safety of vibration exercise. Second, the results of this study are specific to healthy individuals exposed to 10 minutes of vibration, 4 mm of peak-to-peak displacement, at 30 Hz with 45° of knee flexion. The safety of WBV in other postures, frequencies, amplitudes, and populations is not supported by this study. Future research is needed to support the safety of other protocols. Until such evidence is available, strength and rehabilitation practitioners should carefully consider the appropriateness before implementing these protocols.

Practical Applications

A single bout of static squats with 45° of knee flexion while undergoing WBV exercise at 30 Hz with 4 mm of vertical displacement does not cause a significant decrease in neurocognition. It is likely that the head accelerations resulting from this protocol are not sufficient to cause acute injury. Therefore, vibration under these conditions is probably safe for healthy populations in strength, conditioning, and rehabilitation settings. However, research is needed to test potential harmful effects of vibration exercise with different postures, vibration frequencies, amplitudes, and long-term training with WBV, which may result in greater or accumulative head accelerations.

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